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# Growth and Yield of a 59-Year-Old Red Pine Plantation (Plot 99) in Northern Minnesota

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ABSTRACT.—Presents yield in number of trees, basal area, diameter and height distribution, and total commercial volumes after six thinnings in a red pine stand.

KEY WORDS: *Pinus resinosa* Ait., spacing/thinning, volumes, heights.

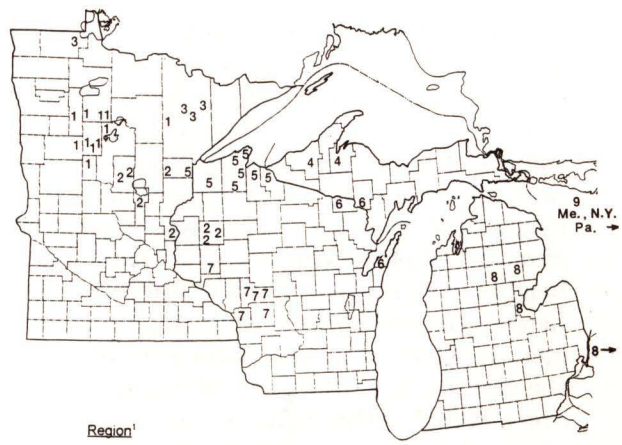
Red pine (*Pinus resinosa* Ait.) is the most common of the hard pines in the Northeastern United States and southeast Canada. It ranges in a band from New Brunswick to Northeastern U.S., and west across Canada to Manitoba. Its southern limit includes the northern portions of the Lake States. A century ago red pine made up about one-third of the 2.2 million acres of pine forests in the Lake States (Benzie 1977). Now it covers 1.568 million acres (Kingsley 1991; Leatherberry 1991, 1994a, 1994b; Murray 1991; Roussopoulos 1992; Schmidt 1993, 1994; Spencer *et al.* 1988).

In this note, I present red pine growth and yield data from "Plot 99" on the Pike Bay Experimental Forest in north-central Minnesota. This experimental plantation was established in 1937 to test the genetic variation of red pine growth from 48 pine seed sources in the United States and Ontario. It was thinned for the first time in 1951 and set up to accommodate a growth and yield study.

## METHODS

The red pine plantation is located on the Pike Bay Experimental Forest near Cass Lake in Cass County, Minnesota (lat. 47°25', long. 94°30'). The ecological land type phase (ELTP) is e11 (personal communication, John Almendinger, Chippewa National Forest). The site is on a gently undulating till plain. The soils of this ELTP typically have 22 to 39 inches of fine sand, loamy fine sand, very fine sandy loam over sandy loam, clay loam over loam, or sandy clay loam. Coarse fragments (from 1 to 10 percent) are found throughout the soil profile. Soils are well drained with mottles of low chroma. Bright mottles are sometimes found deeper than 40 inches. These soils are formed from outwash deposited over glacial till, and local inclusions of till may be found in the otherwise sandy landscape.

The 1.4-acre site had been cleared, plowed, and disked before being planted with 2-1 red pine at a 4x4 foot spacing. The seed sources were grouped into nine regions as proposed by Rudolf (1947). Trees were distributed across the plot with each east-west row representing a region (figs. 1 and 2). All herbaceous and woody competition was controlled by hand-weeding through 1940.




Region[1]

1 - NW Minnesota
2 - Brainerd MN to Cameron WI
3 - NE Minnesota
4 - Upper Peninsula MI
5 - Head-of-the-Lakes WI
6 - NE Wisconsin-southern UP. MI
7 - East-central WI
8 - Lower MI-Angus, Ontario
9 - Maine-New York-Pennsylvania

[1]from Buckman (1962)

Figure 1.—*Red pine seed source locations by region for Plot 99.*

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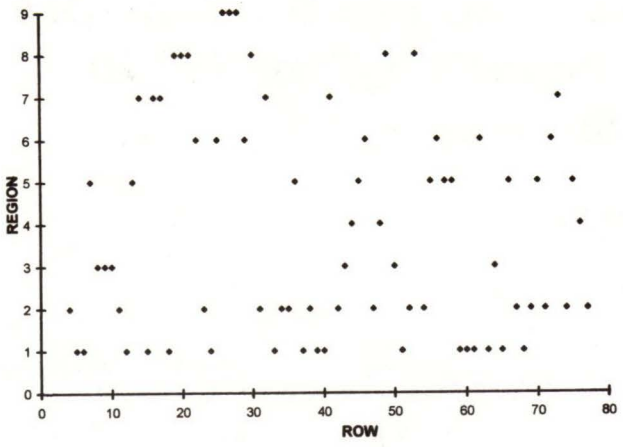


Figure 2.—*Red pine distribution by region and row.*

The stand was measured (d.b.h. and heights) after the 1950, 1955, 1960, 1966, 1971, 1976, 1981, 1983, 1988, and 1993 growing seasons. The trees were thinned in 1951 to prevent stagnation and to prepare the plantation for a growth and yield study. Trees of poor form or vigor were hand-thinned in 1951 and 1956. In 1983 and 1993, smaller trees were removed, maintaining a uniform spacing. Residual basal area ranged from 81 to 94 $ft^2$/acre after the 1950, 1955, 1960, and 1966 measurements, and to 139-140 $ft^2$/acre after stand measurements in 1983 and 1993.

After the 1971 remeasurement, the thinning schedule was extended to a 10-year interval and the measurement plot was reduced to 1 acre. Basal area in 1981 was still too small for a commercial sale, so thinning was postponed until after the 1983 stand measurements. Total height of all trees on the plot was measured after the 1994 growing season. Diameters and heights were measured using diameter tapes, a height pole (early measurements), and clinometer. In 1995, three transects were run across the plantation starting at row 5 and continuing every 10th row thereafter to measure soil depths using a bucket auger (fig. 3). For this note, only the trees in the 1-acre plot were analyzed.

## RESULTS AND DISCUSSION

Red pine yield and growth summaries are presented for measurements taken in 1951 through 1993 (tables 1 and 2). Removals from the thinnings are shown in table 3. Site index is 69 feet (at 50 years).

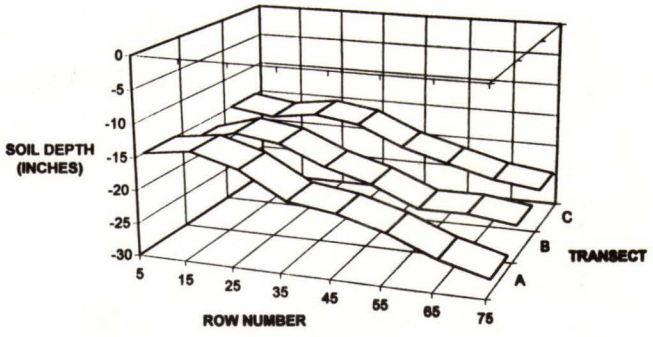


Figure 3.—*Soil depths to till - Plot 99.*

Buckman and Buchman (1962) reported that the 48 sources of seed varied little in total height growth at 27 years of age. Heights in 1993 ranged from 73 to 84 feet at 59 years of age. Plotting the 1993 tree heights by row showed a height difference across the plantation, so further measurements were taken. In the spring of 1995, heights were determined on all the trees and soil depths were measured to the clayey till. Heights in 1994 plotted by soil depth (fig. 4) also suggest a site difference, although the correlation coefficient is significant (P=0.00). A linear regression model to test whether height caries by the region of seed collection or soil depth could be:

$$HT94 = a+b*\text{soil depth} + c*\text{Region 2} + d*\text{Region 4} + e*\text{Region 6} + e_i$$

where

**Regions 2, 4, and 6 are dummy variables equal to 0**

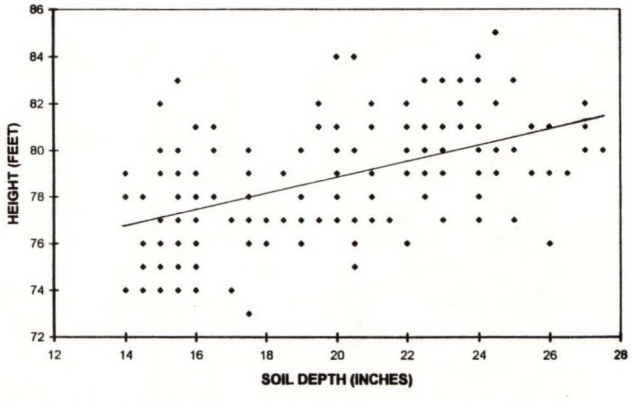


Figure 4.—*Red pine heights (1994) by soil depth.*

HT94 = tree height (feet)

a = 70.95 b = 0.33 c = 1.73 d = 0.52
e = 1.63

$e_i$ = 1.99 (error of estimate)

Auten (1945) and Gaiser (1950) showed that depth to subsoil was highly correlated with site index of yellow poplar and loblolly pine. Steinbrenner (1963) also found a strong positive relation between soil depth and site index of Douglas-fir. Because tree height is an indicator of site index, the same holds true for heights (fig. 4). With the seed sources distributed across the plantation, height difference due to seed source was not confounded by intra-site variability.

Fifteen percent (405 trees) of the original 2,722 trees died in the first 16 years (23 trees/yr). Only 10 trees died after the 1951 thinning (table 1). In 1950, 30 percent of the trees (713) had diameters greater than 3.5 inches. By 1955 (at age 21), 87 percent (1,230 trees) had diameters greater than 3.5 inches. Only five trees were <3.5 inches d.b.h. at age 26.

Numbers of trees per acre by diameter class (*i.e.*, 2 inches = 1.6-2.5 inches) (fig. 5) show the

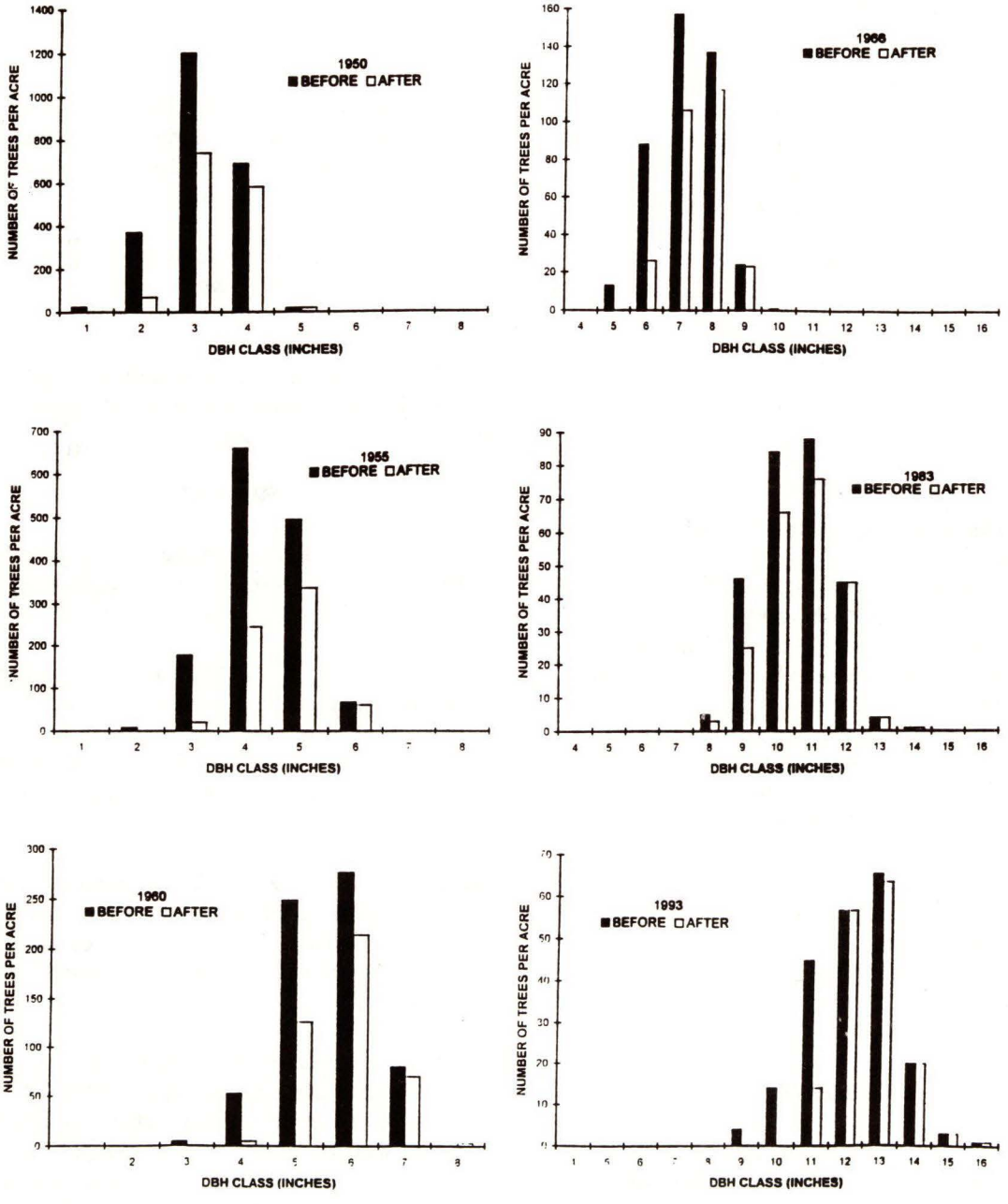


Figure 5.—*Tree distribution by d.b.h. class before and after thinning.*

diameter distribution before and after the six thinnings from below. In 1950 and 1955 combined, 1,642 trees (71 percent) were removed.

Annual basal area growth from ages 16 to 21 was rapid (11.5 $ft^2$/acre/year) (fig. 6). It declined 6.5 $ft^2$/acre/year during the 1955-1966 decade, then dropped about 0.1 $ft^2$/acre/year thereafter to 1993 (age 59). If we use Buckman's (1962) basal area equation for the same data, annual basal area growth declines more gradually from 7.0 $ft^2$/acre/year at age 21 to 5.1 $ft^2$/acre/year at age 59 (fig. 6). (The data for Buckman's equation are averages of many different stands, and the site index of Plot 99 is higher than the data used in the equation formulated by Buckman).

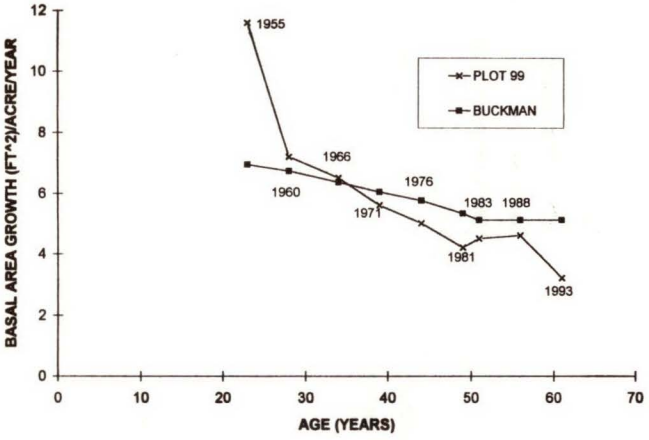


Figure 6.—*Basal area growth - Plot 99.*

Cumulative diameter distributions every 10 to 12 years show how the trees grew for 41 years from the initial study installation at age 16 to 59 years (fig. 7). In the 21 years between 1950 and 1971, the trees grew an average of 5.5 inches in diameter (0.26 inches/year), and the next 22 years, they grew an average of 3.5 inches (0.16 inches/year). Although diameter growth in the last 22 years was less, the trees produced 171 cubic feet more volume.

Mean annual increment from 1950 to 1993 (age 16-49) was 184 $ft^3$ and 1.8 cords/acre/year for Plot 99. Height growth comparisons by region for ages 16, 21, 26, 32, and 59 are shown in table 4.

## SUMMARY

Mean height growth by region, 27 years after planting, showed no statistically significant differences.

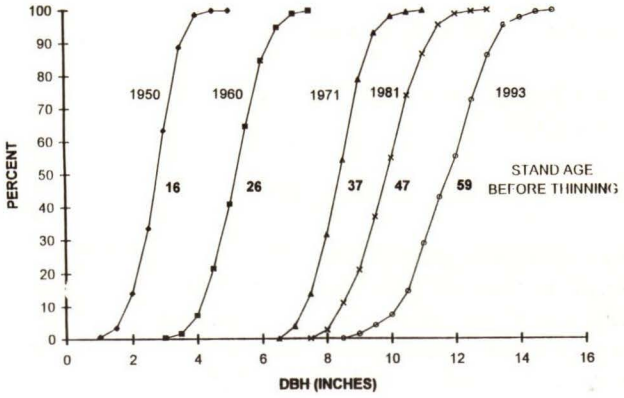


Figure 7.—*Cumulative tree distribution by d.b.h. class.*

Diameter growth in a high density stand (2,417 trees/acre) responded quickly to removal of 71 percent of the trees in two thinnings at ages 16 and 21.

Basal area, cubic feet, cords, and board feet values for Plot 99 data were closed to modeled estimates by Buckman (1962).

Tree heights increased as soil depths increased across the plantation, a soil-site relationship, independent of seed source.

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Table 1.—*Red pine yield summaries (per acre) - Plot 99*

| | 1950 | | 1955 | | 1960 | | 1966 | | 1971 | 1976 | 1981 | 1983 | | 1988 | 1993 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Before thin | After thin | Before thin | After thin | Before thin | After thin | Before thin | After thin | Not thinned | Not thinned | Not thinned | Before thin | After thin | Not thinned | Before thin | After thin |
| Number of trees | 2,317 | 1,417 | 1,408 | 666 | 666 | 419 | 418 | 273 | 273 | 273 | 273 | 273 | 219 | 219 | 219 | 159 |
| Basal area ($ft^2$)[a] | 134 | 94 | 152 | 82 | 118 | 81 | 120 | 85 | 113 | 138 | 159 | 168 | 139 | 162 | 178 | 140 |
| Cubic foot volume[b] | 1,142 | 803 | 1,915 | 1,039 | 1,916 | 1,311 | 2,374 | 1,691 | 2,541 | 3,665 | 4,396 | 4,768 | 3,958 | 4,987 | 5,746 | 4,513 |
| Cords[c] | 11.1 | 7.8 | 18.6 | 10.1 | 18.6 | 12.7 | 23.0 | 16.4 | 24.6 | 35.5 | 42.6 | 46.2 | 38.3 | 48.3 | 55.7 | 43.8 |
| Board feet[d] (trees > 9.0" d.b.h.) | | | | | | | 326 | 280 | 6,123 | 14,983 | 20,716 | 23,263 | 19,722 | 25,426 | 29,307 | 23,055 |
| Board feet[d] (trees > 12.0" d.b.h.) | | | | | | | | | | 114 | 1,402 | 3,485 | 3,485 | 12,217 | 18,969 | 18,708 |
| Average height (ft) | 20.9 | | 30.9 | | 39.8 | | 48.5 | | 55.0 | 65.0 | 67.6 | 69.6 | | 75.4 | 78.8 | |
| Mean d.b.h. (in) | 3.19 | 3.45 | 4.37 | 4.72 | 5.63 | 5.92 | 7.20 | 7.54 | 8.68 | 9.58 | 10.29 | 10.56 | 10.75 | 11.59 | 12.17 | 12.70 |
| Age from seed | 16 | | 21 | | 26 | | 32 | | 37 | 42 | 47 | 49 | | 54 | | 59 |

[a]Basal area = 0.0054541 ($d.b.h.^2$)
[b]Cubic foot volume = 0.4085 (BA x Height)
[c]Cords = 0.003958 (BA x Height)
[d]Board feet = 2.084 (BA x Height)

Table 2.—*Red pine growth before thinning at the end of 2- to 6-year periods (per acre) - Plot 99*

| | 1950-55 | (/yr) | 1955-60 | (/yr) | 1960-66 | (/yr) | 1966-71 | (/yr) | 1971-76 | (/yr) | 1976-81 | (/yr) | 1981-83 | (/yr) | 1983/88 | (/yr) | 1988/93 | (/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Basal area ($ft^2$) | 57.66 | 11.53 | 32.49 | 6.50 | 39.19 | 6.53 | 27.72 | 5.54 | 24.93 | 4.99 | 21.14 | 4.23 | 8.54 | 4.27 | 22.60 | 4.52 | 16.65 | 3.33 |
| Cubic foot volume | 1,112 | 222 | 877 | 175 | 1,063 | 177 | 850 | 170 | 1,124 | 225 | 731 | 146 | 372 | 186 | 1,029 | 206 | 759 | 152 |
| Cords | 10.8 | 2.16 | 8.5 | 1.70 | 10.3 | 1.72 | 8.2 | 1.64 | 10.9 | 2.18 | 7.1 | 1.42 | 3.6 | 1.8 | 10.0 | 2.0 | 7.4 | 1.48 |
| Board feet (trees > 9.0" d.b.h.) | | | | | | | 5,843 | 1,169 | 8,860 | 1,772 | 5,733 | 1,147 | 2,547 | 1,274 | 5,704 | 1,141 | 3,881 | 776 |
| Board feet (trees >12.0" d.b.h.) | | | | | | | | | | | 1,288 | 258 | 2,083 | 1,042 | 8,732 | 1,746 | 6,752 | 1,350 |
| Height (ft) | 10 | 2.0 | 8.9 | 1.78 | 8.7 | 1.45 | 6.50 | 1.30 | 10.0 | 2.00 | 2.6 | 0.52 | 2.0 | 1.0 | 5.8 | 1.16 | 3.4 | 0.68 |
| Mean d.b.h. (in) | 0.92 | 0.184 | 0.91 | 0.182 | 1.28 | 0.213 | 1.14 | 0.228 | 0.90 | 0.180 | 0.71 | 0.142 | 0.27 | 0.135 | 0.84 | 0.168 | 0.58 | 0.116 |

Table 3.—*Red pine trees, basal area, and volumes removed (per acre) - Plot 99*

| | 1950 | 1955 | 1960 | 1966 | 1983 | 1993 | Totals |
|---|---|---|---|---|---|---|---|
| Number of trees | 900 | 751 | 247 | 145 | 54 | 60 | 2,158 |
| Basal area ($ft^2$) | 34 | 69 | 37 | 34 | 28 | 38 | 246 |
| Cubic feet | 339 | 876 | 605 | 683 | 910 | 1,233 | 4,646 |
| Cords | 3.3 | 8.5 | 5.9 | 6.6 | 7.9 | 11.9 | 44.1 |
| Board feet (trees > 9.0" d.b.h.) | | | | 46 | 3,541 | 6,252 | 9,839 |
| Board feet (trees > 12.0" d.b.h.) | | | | | | 261 | 261 |

Table 4.—*Red pine height comparisons by regions (1950-1994) - Plot 99*

| Region | Height 1950 | | | Height 1955 | | | Height 1960 | | | Height 1966 | | | Height 1993 | | | Height 1994 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | average HT | ± (SD) | N | average HT | ± (SD) | N | average HT | ± (SD) | N | average HT | ± (SD) | N | average HT | ± (SD) | N | average HT | ± (SD) |
| 1 | 83 | 21.1 | 2.2 | 360 | 31.5 | 2.1 | 171 | 40.0 | 2.4 | 9 | 48.2 | 0.4 | 7 | 78.1 | 3.0 | 43 | 78.1 | 2.2 |
| 2 | 438 | 21.3 | 2.5 | 265 | 31.9 | 2.4 | 124 | 40.2 | 2.3 | 7 | 49.6 | 3.9 | 7 | 80.0 | 2.6 | 22 | 79.3 | 2.0 |
| 3 | 222 | 20.9 | 2.4 | 134 | 31.6 | 2.3 | 60 | 40.0 | 2.6 | 6 | 48.5 | 1.8 | 5 | 76.8 | 4.3 | 17 | 78.2 | 3.1 |
| 4 | 82 | 20.7 | 2.3 | 51 | 31.3 | 1.9 | 22 | 39.6 | 2.1 | 1 | 47.0 | - | 1 | 78.0 | - | 2 | 79.0 | 2.8 |
| 5 | 297 | 21.0 | 2.2 | 176 | 31.3 | 2.2 | 82 | 39.6 | 2.6 | 3 | 49.9 | 3.2 | | no trees | | 13 | 79.2 | 2.0 |
| 6 | 223 | 21.5 | 2.1 | 139 | 32.0 | 2.2 | 69 | 40.8 | 2.1 | 5 | 48.2 | 0.8 | 4 | 80.3 | 1.7 | 23 | 79.4 | 1.6 |
| 7 | 191 | 21.6 | 1.9 | 117 | 31.7 | 2.0 | 57 | 40.1 | 2.2 | 5 | 48.1 | 1.3 | 4 | 77.8 | 2.2 | 13 | 76.7 | 1.7 |
| 8 | 170 | 21.2 | 2.5 | 111 | 31.6 | 2.2 | 55 | 40.1 | 2.4 | 6 | 49.0 | 1.7 | 5 | 79.0 | 4.0 | 21 | 78.9 | 2.0 |
| 9 | 94 | 20.3 | 2.3 | 60 | 30.4 | 2.4 | 26 | 38.9 | 2.7 | 1 | 47.5 | - | 1 | 76.0 | - | 5 | 76.4 | 1.8 |
| Total or mean | 2,300 | 21.1 | 2.3 | 1,413 | 31.6 | 2.2 | 666 | 40.1 | 2.4 | 43 | 48.6 | 2.0 | 34 | 78.6 | 3.1 | 159 | 78.8 | 2.5 |
| Range | | 18.8-23.4 | | | 29.4-33.8 | | | 37.7-42.5 | | | 46.6-50.6 | | | 75.5-81.4 | | | 76.3-81.3 | |

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